EARTHQUAKE WORKING GROUPS, DATABASE UPDATES, AND PALEOSEISMIC FAULT STUDIES, UTAH

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INVESTIGATIONS UNDERTAKEN

The Utah Geological Survey (UGS), in cooperation with the U.S. Geological Survey (USGS) and Utah Seismic Safety Commission, convened a third annual series of earthquake working group meetings in March 2005. In the working group meetings we developed priorities for 2006 earthquake research and reviewed the 2003 (revised in 2004) multi-year plans for developing the next generation of earthquake ground shaking and liquefaction maps for Utah. In support of the working groups' effort, we updated our interactive Quaternary fault and fold, shallow shear-wave-velocity, deep-basin-structure, and geotechnical landslide shear-strength databases.

In addition, the UGS is performing field studies of the Collinston and Clarkston Mountain segments of the Wasatch fault zone (WFZ) to complete UGS and USGS surficial geologic studies of Utah segments of the WFZ. These studies are used in paleoseismic characterization of the fault for both the UGS and USGS Quaternary fault databases used in the National Seismic Hazard Maps (NSHMs). We are also developing a multi-segment rupture model for the WFZ for use by the USGS to evaluate its effects on ground motions in the NSHMs. Although scheduled to convene a Basin and Range Province Earthquake Working Group as recommended in Western States Seismic Policy Council (WSSPC) Policy Recommendation 05-5, we postponed this activity until 2006.

RESULTS

Working Groups

Meetings of the Utah Ground Shaking, Liquefaction, and Quaternary Fault Parameters Working Groups were held on March 2-4, 2005. Working groups discussed the previous year's work, reviewed 2003 long-term plans (revised in 2004), identified partnerships and projects for future proposals, and developed priorities for 2006 earthquake research. Nearly 50 members attended the various working group meetings.

The Ground Shaking Working Group emphasized developing a community velocity model for use in developing detailed spectral-acceleration maps for ground motions at various periods that consider both shallow shear-wave velocities (Vs30) and deep-basin structure. The Liquefaction Working Group is continuing its NEHRP-funded pilot project in northern Salt Lake Valley and expanding it to include southern Salt Lake Valley. The Utah Quaternary Fault Parameters Working Group finished its final technical report in 2004, and reviewed new paleoseismic data and priorities for future paleoseismic studies. The Earthquake-Induced Landslide Working Group did not meet this year.

Databases

To help working groups develop priorities for 2006, the UGS updated the Quaternary fault and fold, shallow shear-wave velocity (Vs30), deep-basin-structure, and geotechnical landslide-shear-strength databases. The Quaternary fault and fold database was updated with trenching and mapping data collected since compilation of Black and others (2003), and consensus values for recurrence intervals and slip rates for trenched faults determined by the Utah Quaternary Fault Parameters Working Group (Lund, 2005). The shallow shear-wave-velocity database was updated to include 2004 spectral-analysis-of-surface-wave (SASW) data collected under another NEHRP-funded project. No new data were available for the deep-basin-structure database. The geotechnical landslide shear-strength database was updated with soil-test data from various sources, principally from geotechnical consultants and the Utah Department of Transportation.

Paleoseismic (Non-Trenching) Studies of the Collinston and Clarkston Mountain Segments of the Wasatch Fault Zone

We are conducting a non-trenching paleoseismic study of the Collinston and Clarkston Mountain segments of the Wasatch fault zone in northern Utah (figure 1). Our work has consisted of review of published and unpublished geologic mapping along the segments; aerial-photo and field reconnaissance to verify the existing geologic mapping, particularly map relations among Tertiary and Quaternary deposits, fault scarps, and shoreline scarps formed during stillstands of the latest Pleistocene Bonneville lake cycle; and measurement of 13 profiles across fault and shoreline scarps to obtain data for empirical and diffusion-equation age determinations.

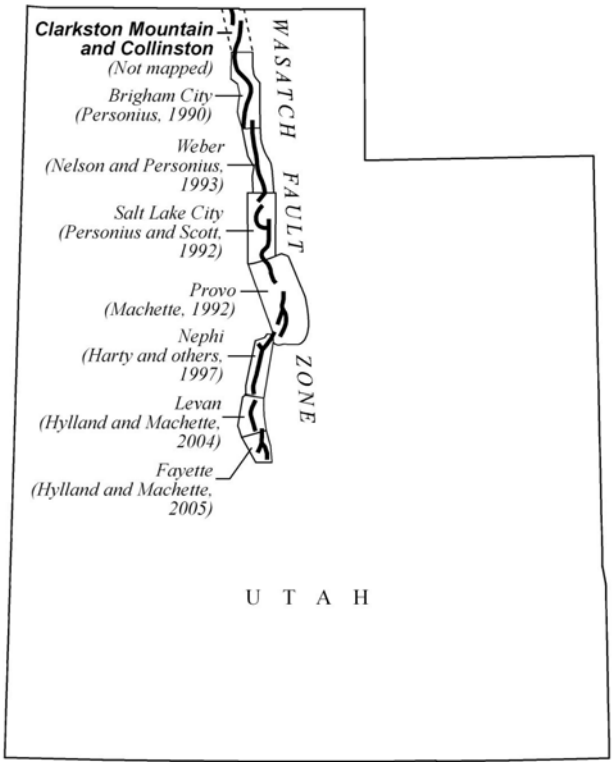

Figure 1. *Index map of Wasatch fault zone in Utah showing location of Collinston and Clarkston Mountain segments, and published 1:50,000-scale surficial-geologic strip maps.*

Along the Collinston segment, the only fault scarps on Quaternary deposits that have been reported by previous workers are in the segment-boundary area (Coldwater Canyon reentrant of Oviatt [1986], near Honeyville) between the Collinston segment and Brigham City segment to the south. Personius (1990) interpreted these fault scarps as the northern end of Brigham City-segment ruptures, and we concur. As with previous investigators, we likewise identified no fault scarps on Quaternary deposits, principally Lake Bonneville and younger deposits, north of the Coldwater Canyon area. We suspect that the lack of Holocene movement on the Collinston segment may be related to strain partitioning as reflected by activity on the West and East Cache fault zones, both of which lie within 20 km east of the Collinston segment and have undergone movement in the Holocene (McCalpin, 1994; Solomon, 1999).

Although the scarps in the Coldwater Canyon area do not appear to be associated with rupture of the Collinston segment, we nevertheless measured 11 scarp profiles in this area: three profiles cross scarps mapped by previous workers as fault scarps, six cross suspected fault scarps, and two cross the Bonneville shoreline. The suspected fault scarps are short scarps that are otherwise buried by unfaulted Holocene fan alluvium. One of these scarps is mapped as a fault scarp by Personius (1990), but the others have not been mapped. We interpret these scarps to be fault scarps, and not shoreline scarps, based on their position between the Bonneville and Provo shorelines of the Bonneville lake cycle, and their slight obliquity to topographic contours. The purpose of the fault-scarp profiles is to compare the resulting age data with the surface-faulting chronology of the Brigham City segment that has been developed from paleoseismic trenching studies to the south (Personius, 1991; McCalpin and Forman, 2002), to evaluate along-strike temporal variation in rupture patterns. This work is still in progress. We are also using the profile data to evaluate fault slip rate and initiation age through application of diffusion modeling in a manner similar to that done by Mattson and Bruhn (2001) and DuRoss and Bruhn (2004).

The two profiles across the Bonneville shoreline were measured to provide data for calibrating diffusion-equation age determinations of the fault scarps, namely determining an appropriate value of diffusivity. Unfortunately, the scarp-slope and ambient- (far-field) slope angles of these shoreline scarps are outside (greater than) the range of most published datasets (for example, Andrews and Bucknam, 1987; Hanks and Andrews, 1989), so we are presently evaluating the applicability of these data in determining a meaningful diffusion constant.

The only fault scarp on late Quaternary deposits that we identified along the Clarkston Mountain segment is at the mouth of Elgrove Canyon, where Biek and others (2003) described the scarp as lying above the Bonneville shoreline and cutting late Pleistocene fan alluvium. The 40-m-long scarp is at a U.S. Forest Service trailhead, and there has been some localized ground disturbance on the downthrown side associated with vehicle parking as well as minor development of a small spring. We measured two profiles across the scarp where we believe any ground disturbance is minor to nonexistent. The profiles show a composite scarp morphology resulting from multiple (probably two) surface-faulting events. The profile data indicate a maximum scarp height of about 7 m and a maximum scarp-slope angle of about 15º, and total net vertical tectonic displacement (NVTD) of 3.6 m. The most recent event (MRE) produced 2.2 m of NVTD, and the earlier event produced 1.4 m of NVTD. Empirical relations between scarp-slope angle and scarp height indicate the MRE occurred shortly prior to the Bonneville highstand of the Bonneville lake cycle (18-16.8 ka), consistent with geologic evidence suggesting that the most recent scarp-forming event predates the end of the Bonneville lake cycle (Machette and others, 1992; Biek and others, 2003). Similar to the Collinston segment, the absence of Holocene movement on the Clarkston Mountain segment may be related to Holocene activity on the West and East Cache fault zones to the east.

Wasatch Fault Zone Multi-Segment Rupture Model

We performed a preliminary analysis of the potential for multi-segment ruptures (MSRs) on the Brigham City (BC), Weber (W), Salt Lake City (SLC), and Provo (P) segments of the Wasatch fault zone (WFZ). Our investigation focused on (1) updating and revising the WFZ paleoearthquake space-time diagram with the Utah Quaternary Fault Parameters Working Group earthquake-timing estimates (Lund, 2005) and new preliminary paleoseismic data for the W and P segments, (2) formulating criteria to quantify the potential for MSRs along the WFZ, and (3) constructing a preferred MSR model for the WFZ. Work to be completed includes the discussion and improvement of our preferred WFZ MSR model through a working-group consensus process.

Sixteen earthquakes occurred after ~6.5 ka on the BC, W, SLC, and P segments of the WFZ, resulting in 22 possible earthquake pairs (on adjacent segments) that have overlapping consensus time ranges. We defined specific criteria, based on the consensus preferred earthquake timing and estimated two-sigma ranges in Lund (2005), to characterize the MSR potential between the earthquake pairs as high, medium, low, or very low/nonexistent. We also analyzed the chronological control for each earthquake, ranking our confidence in the paleoseismic data as high to low (or unknown) based on the number of trench sites and number and type of limiting numerical ages.

Of the 22 possible earthquake pairs, four have a high potential for representing a MSR, three have medium MSR potential, and four have low potential. The 11 remaining pairs have either very low MSR potential or the potential is unknown due to incomplete paleoseismic data. We identified at least one high-potential earthquake pair and one medium-potential earthquake pair per set of adjacent segments (segment pairs), and low-potential pairs on the BC-W and SLC-P segments but none on the W-SLC segments. Our confidence in the paleoseismic data ranges from low to high, with medium-MSR-potential earthquake pairs generally associated with the best quality data. As expected, the paleoseismic confidence level is highest for the youngest earthquakes on each segment, and generally decreases with increasing earthquake age.

Our analysis shows that the potential for MSRs on the WFZ is significant, but that the paleoseismic data necessary to have confidence in such ruptures is limited. We are confident that MSRs among the BC, W, SLC, and P segments are possible; however, given the sparse displacement data and prevalence of low- to medium-MSR-potential earthquake pairs and low to medium data confidence, single-segment ruptures over the long-term history of the fault are likely more common. Determining which WFZ-segment pairs are more likely to rupture together is difficult due to the limits of our paleoseismic data. However, based on our preliminary analysis, MSRs on the BC-W and SLC-P segments may occur more frequently than W-SLC MSRs. Although the possible W-SLC MSRs are associated with medium- to high-confidence data, the majority of the possible MSRs are between the BC-W and SLC-P segments. Additionally, the W-SLC segment boundary is relatively more complex than the BC-W and SLC-P segment boundaries, possibly indicating a more persistent boundary to rupture propagation. Vertical-displacement data for the central segments roughly support BC-W and SLC-P MSRs (indicating large amounts of slip near the segment boundaries), but are lacking for the southern part of the W and northern part of the SLC segments.

To generate a MSR model for the WFZ we defined five rupture scenarios for the BC, W, SLC, and P segments, each representing one possible mode of failure of the fault during one earthquake cycle (following the Working Group on California Earthquake Probabilities, 2003). We created preliminary fault-rupture models, each having weighted combinations of the different rupture scenarios based partly on our MSR-potential analyses. Each model represents one possible long-term mode of earthquake rupturing on the central part of the WFZ. Our preferred MSR model specified individual weights for each fault-rupture model, favoring individual segment ruptures to MSRs, but including a moderate percentage of MSRs between adjacent segments. In general, our individual scenario and model weights are qualitative and simplified; the expert opinion of a working group is necessary to define appropriate weights. Additionally, we plan to update the model by incorporating new paleoseismic data for the W, P, and Nephi (N) segments, and analyzing the potential for MSRs between the P and N segments.

Basin and Range Earthquake Working Group

The Basin and Range Province Seismic Hazard Summit II in May 2004 recommended convening a Basin and Range Province Earthquake Working Group (BRPEWG) to develop consensus regarding characterization of Basin and Range faults for the NSHMs. The recommendation was adopted as WSSPC Policy Recommendation 05-5. The UGS proposed to convene the working group and hold a meeting in fall 2005, but this was postponed due to the large number of competing meetings in the area at that time (WSSPC Annual Meeting in Boise, Association of Engineering Geologists Annual Meeting in Las Vegas, Geological Society of America Annual Meeting in Salt Lake City), and the desire to hold the meeting in conjunction with or around the same time as the 2006 NSHM Intermountain West workshop in spring 2006. We discussed membership, topics for discussion, and protocols/formats for arriving at consensus at the 2005 Utah Earthquake Working Group meetings and 2005 WSSPC Basin and Range Committee meeting. The BRPEWG meeting is presently scheduled for March or April 2006.

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REPORTS PUBLISHED

All working group plans are posted at the UGS Web site (geology.utah.gov). Updates to the Quaternary fault and fold map and database were submitted to the USGS to update the Quaternary fault and fold database of the U.S. Results of all 2004 studies and plans for 2005 studies were presented at the March 2005 working group meetings.

AVAILABILITY OF DATA

The final report of the Utah Quaternary Fault Parameters Working Group was published as Utah Geological Survey Bulletin 134. The updated shallow shear-wave-velocity, deep-basin-structure, and geotechnical landslide shear-strength databases (HTML Image Mapper®, version 3.0) are available from Greg McDonald, 801-537-3383, email gregmcdonald@utah.gov. The updated Quaternary fault and fold database has been incorporated into the USGS Quaternary fault and fold database of the U.S. and will be available at the UGS Web site (geology.utah.gov) in 2006.

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NON-TECHNICAL SUMMARY

The UGS held the 2005 Utah Ground Shaking, Liquefaction, and Quaternary Fault Parameters Working Group meetings in March 2005, co-sponsored by the USGS and Utah Seismic Safety Commission. We presented and discussed results of 2004 research, reviewed existing earthquake-hazard mapping plans, and established priorities for 2006 research. In support of this effort, the UGS updated databases completed in 2004. We also performed surficial paleoseismic investigations of the Collinston and Clarkston Mountain segments of the northern Wasatch fault zone (WFZ), and developed a multi-segment rupture model for the central segments of the WFZ. Convening of the Basin and Range Province Earthquake Working Group was postponed until 2006.